Environmental Research 172 (2019) 394–398

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Short communication

Nature-based solutions: Settling the issue of sustainable urbanization

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ARTICLE INFO

Keywords:
Nature-based solutions
DPSIR framework
Ecosystem services
Sustainable urbanization
Climate change
Environmental policy implementation

ABSTRACT

Rapid urbanization presents one of the most urgent challenges of our times. Cities must cope with poor air quality, heat island effects, increased flood risk and the frequency/severity of extreme events (e.g., droughts and heat waves), increasing crime and social inequity, poverty and degraded urban environments, amongst other negative consequences. Climate change adaptation and mitigation as well as sustainable management are therefore key challenges for cities in Europe and around the world. What must be developed therefore is a robust, wide evidence-base and reference framework of nature-based solutions (NBS) – measures that mimic the complex features and processes of natural ecosystems – for local/regional city authorities and other policy and decision makers to increase climate resilience and address inclusive urban regeneration in cities. In response to this need, we propose an applicative framework for NBS using the structure of the DPSIR (Driving force–Pressure–State–Impact–Response) model, in conformity with European Community standards. Indeed, under the umbrella of the EC's Framework Program – Horizon 2020 – international institutions, scientific experts and policy makers worldwide are seeking to increase collaboration with cities to enhance ecosystem services and develop the evidence-base for the economic, social and environmental benefits of nature-based solutions. They are eager to exchange knowledge and inspire positive action for nature in urban areas to meet their growing social and environmental challenges. The time has come to acknowledge NBS as the most fitting response to the numerous challenges posed by our changing climate and for the realization of sustainable and healthy cities. It is hoped that this article will pioneer others in settling the issue for NBS as the undisputable answer to challenged urban landscapes and societies globally.

1. Introduction

In the last three decades, scientists from a wide range of disciplines have ascertained the effects of urbanization on different socio-economic and environmental factors, such as social inequity, infrastructure development and air and water pollution, and explained how these factors can undermine efforts to promote a more sustainable society (Kalnay and Cai, 2003; Bloom et al., 2008; Grimm et al., 2008; Zhao et al., 2013). This is backed by the fast-growing literature, which highlights the adverse effects of urbanization on a range of ecosystem services (ESS) and, consequently, on human health and wellbeing (Eigenbrod et al., 2011; Güneralp et al., 2013; Kusch et al., 2016; Wentworth, 2017). What is less obvious are the ways and means for balancing these effects through adaptation measures tailored to sustainability. To this end, an emerging approach, which contrasts the traditional 'grey infrastructure' approach (Davies and Lafortezza, 2018), involves the adoption of measures that mimic the complex features and processes of natural ecosystems, namely "nature-based solutions" (NBS) (EC, 2015; Faivre et al., 2017). The term itself embraces the main goal of NBS, which is to provide solutions rather than mere approaches or general concepts to address societal challenges, such as urbanization. Not surprisingly, NBS have been initially solicited by decision and policy makers (e.g., International Union for Conservation of Nature [IUCN]), and gradually thereafter by researchers in various disciplines such as environmental psychology (Panno et al., 2017) and environmental and social research (Lin and Qi, 2017). In their seminal work, Sutherland et al. (2014) identified a list of 296 potential solutions for maintaining and enhancing regulating ESS, 25 of which pertain to the urban system, such as the use of permeable surfaces and vegetation, where possible, in hard landscape construction (Appendix 1, solution no. 132).

It took less than one year for the European Commission's Expert Group on 'Nature-Based Solutions and Re-Naturing Cities' to grasp the potential of NBS as a unifying paradigm to advance sustainable urbanization in European cities. A foundation stone in this process has been the timely activation of funding initiatives, such as Horizon 2020 (H2020), supporting knowledge transfer and exchange of practices among decision and policy makers, researchers, public entities, and small-medium enterprises in Europe; the message is as simple as potent: if there is a will to solve environmental issues in cities, then NBS are the answer (Vujcic et al., 2017; Lafortezza et al., 2018). Based on this understanding, decision and policy

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https://doi.org/10.1016/j.envres.2018.12.063
Received 24 August 2018; Received in revised form 16 December 2018; Accepted 25 December 2018
Available online 28 December 2018
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makers are encouraged to approach science-driven minds to co-design and co-develop solutions, making urban areas more sustainable and resilient to climate change. However, this should be achieved in a relatively short-term period (within 5 years), because the time for pronunciations is over and concrete solutions are needed. Rapid urbanization has grown continuously over the past 50 years and recent prospects from the UN are anything but encouraging (UN, 2014). Population growth and urbanization are projected to add 2.5 billion people to cities worldwide by 2050, with nearly 90% of the increase concentrated in Asia and Africa (UN, 2014). As a result, new initiatives and calls for actions related to NBS and sustainable urbanization abound on the web and in social media, even beyond the European realm. A remarkable example is the "global campaign on urban forestry", recently launched by "Stefano Boeri Architetti" (Milan, Italy) at the first World Forum on Urban Forests (Italy, Nov. 2018) (https://www.archdaily.com/886133/urban-forestry-a-call-for-action-by-stefano-boeri-architetti).

Although the concept of NBS is gaining widespread consensus among researchers and policy makers around the globe, there is a need to further formalize its role and potential in relation to the multitude of factors and mechanisms underlying the process of sustainable urbanization. In consequence, this article intends to advance the current debate in favor of NBS by introducing a reference framework for NBS as the appropriate downstream response to co-developing sustainable cities challenged with the mounting pressures of urbanization. Equipping cities with a robust, wide evidence-base and a framework for NBS sets the stage for meeting urban sustainability goals, creating healthy environments and tackling the challenges posed by (global) climate change.

2. NBS applicative framework

Few frameworks exist for acknowledging and assessing the role and co-benefits of NBS and for guiding cross-sectoral projects and policy design and implementation. Raymond et al. (2017a) developed an example of conceptual framework for assessing the co-benefits of NBS across elements of sociocultural and socioeconomic systems, biodiversity, ecosystems and climate. The framework was guided by a review of numerous documents from science and practice within and across ten societal challenges relevant to cities globally, which are: climate mitigation and adaptation, water management, coastal resilience, green space management, air quality, urban regeneration, participatory planning and governance, social justice and social cohesion, public health and wellbeing, and economic opportunities and green jobs. NBS can have environmental, social and economic co-benefits both within and across these societal challenges (Raymond et al., 2017a).

Notwithstanding this and other reputable works, the time is ripe to move forward with a more applicative framework, in conformity with EC standards, to support the process of developing and delivering NBS for sustainable urbanization (Markevych et al., 2017). Considering the complex mechanisms that generally underlie urbanization and its effects on the provision of ESS, the framework should place NBS in the suitable context downstream the overall urbanization cause-effect process. To mainstream this perspective, NBS have been applied herein within the European-born DPSIR (Driving force–Pressure–State–Impact–Response) standardized framework to study their effects on the dynamics of urban areas (Gabrielsen and Bosch, 2003). DPSIR is one of the key decision support tools that have emerged in the last fifteen years to analyze the cause-effect relationships existing between society and the environment and to uphold decisions in response to environmental issues (Gregory et al., 2013; Spanò et al., 2017).

It must be emphasized, nonetheless, that the NBS framework presented herein has the potential of being applied to address other global challenges besides climate change. However, for the purpose of our work in support of the NBS framework we have chosen to focus on the effectiveness of NBS to promote climate resilience and sustainability (from an economic, social and environmental perspective) in urban areas (Lu and Ke, 2018; Wendling et al., 2018), a topic that is currently at the center of debate among international institutions, scientific experts and policy makers.

The proposed NBS framework considers infrastructure development and extensive soil sealing as examples of the main 'driving forces' (D) affecting ESS dynamics in urban areas in the context of changing climate (see Fig. 1).

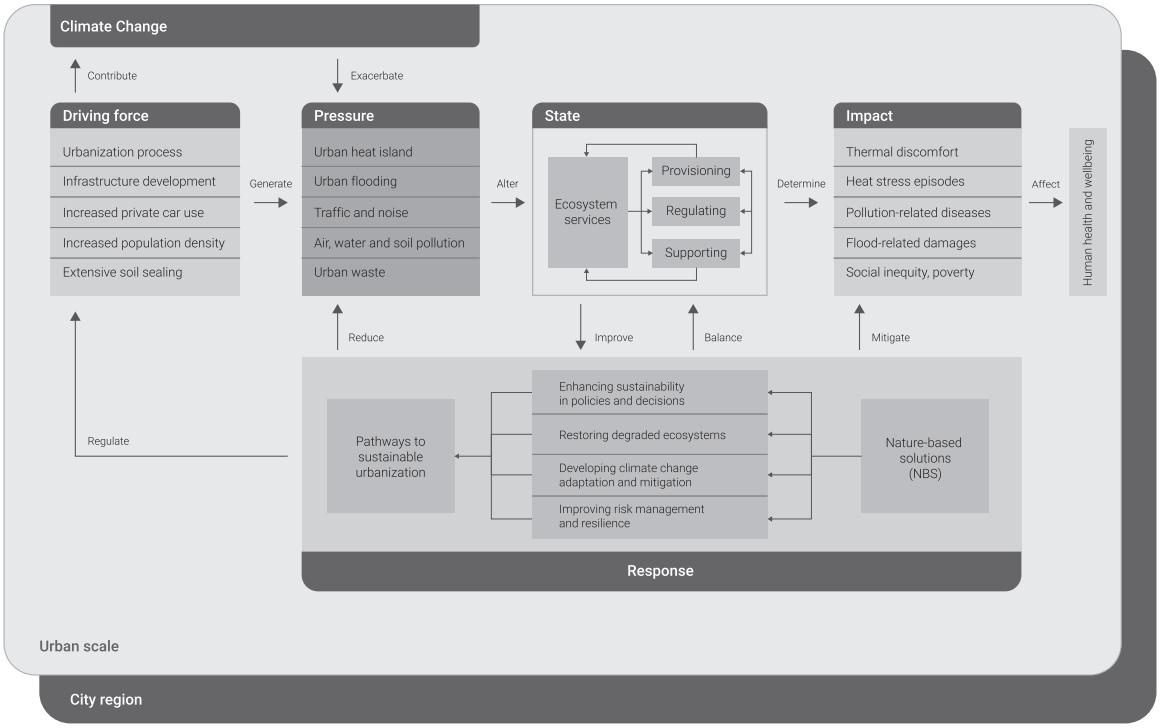

Fig. 1. Nature-based solutions (NBS) applicative framework based on the DPSIR (Driving force–Pressure–State–Impact–Response) model to study their effects on the dynamics of urban areas. The framework emphasizes NBS as *downstream* actions that city managers and policy and decision makers can implement as responses to promote sustainable urbanization in cities and city-regions. The specific components of the DPSIR framework (e.g., driving forces, pressures, impacts) should be assumed as mere examples of the main processes affecting/influencing areas undergoing rapid urbanization. The primary intent is to organize the specific components into a logical standardized framework rather than provide an exhaustive collection of all possible driving forces, pressures, impacts, state, and response.

Through complex interactions with the physical environment, these drivers generate a number of 'pressures' (P), such as urban heat island/waves and air, water and soil pollution, which in turn alter the 'state' (S) of urban areas in terms of ESS, mainly those within the categories of *provisioning*, *regulating*, and *supporting*. These complex and interrelated changes in the state of ESS determine a series of important cascading 'impacts' (I), such as heat stress episodes and flood-related damages that can ultimately have serious consequences on human health and wellbeing (Lafortezza et al., 2009).

To counter the *upstream* impacts of urbanization and its negative effects on ESS, we propose to envision NBS as actions *downstream* that city managers can carry forward as concrete 'responses' (R), for example, by (1) enhancing sustainable urbanization from an economic, environmental and wellbeing perspective, (2) restoring degraded ecosystems to increase their resilience, (3) developing climate change adaptation and mitigation strategies, and (4) improving risk management and resilience, as suggested by the EC's Expert Group on 'Nature-Based Solutions and Re-Naturing Cities' (EC, 2015). These responses shall generate pathways to sustainable urbanization, which in turn, can *regulate* some of the driving forces and *reduce* pressures on urban areas. At the same time, they may directly interact with the 'state' of urban ESS, promoting an effective balance and provision over time, while NBS functions mitigate human health-/wellbeing-related impacts.

This framework presents an alternative perspective on the potential role of NBS to meet the challenge of settling the issue of sustainable urbanization not only at the local level but also at the level of city-region (i.e., metropolitan area). Indeed, most of the issues affecting the long-term sustainability of cities are the consequence of large-scale plans and policies (e.g., interconnected transportation networks, green infrastructure plans, flood management strategies). Hence, there is an urgent need to introduce NBS within the decision-making process at a broader scale. In this regard, during the European Commission's 2014 consultation on structuring a comprehensive R&I policy framework for NBS, a strong recurrent theme was "the need to adapt a broader holistic framework and thinking to promote systemic solutions and system resilience" (EC, 2015, p. 67). The Commission also affirmed the importance of creating a more comprehensive evidence-base for NBS by "devising large-scale demonstration projects for scaling up local solutions to tackle larger scale problems" (EC, 2015, p. 21). Faithful to its recommendations, the European Commission is actively engaged in investing in NBS projects and initiatives to develop sustainable urbanization not only in urban areas but also at larger scales, both in Europe and abroad. This action is in progress under the umbrella of the EC's Framework Program – H2020 – where international institutions, scientific experts and policy makers worldwide seek to increase collaboration with cities to enhance ESS provision and develop the evidence-base for the economic, social and environmental benefits of NBS with the intent to target broader scales. These actors are eager to exchange knowledge and inspire positive action for nature to meet their growing social and environmental challenges. As compelling proof of this claim, a list of projects funded by the EC within the H2020 Framework Program is presented (see Table S1). Among the 12 projects under way, two prime examples of large-scale initiatives are EKLIPSE and ThinkNature. As an ongoing EC-funded initiative, EKLIPSE (Call no. H2020-SC5-2015-one-stage; 2016–2020) is committed to answering requests from policy makers and other societal actors on environmental-related issues. More specifically, EKLIPSE explores the multiple dimensions of impact that NBS may have when implemented at different scales, and the evaluation framework guides the effectiveness of NBS projects to promote climate resilience in urban areas (Raymond et al., 2017b). ThinkNature (Call no. H2020-SC5-2016-OneStageB; 2016–2019) is funded by the H2020 research program with the aim to promote NBS across research, policy, business and non-governmental organizations. These solutions will guide the design of sustainable cities and territories, procure opportunities for economic co-development, and promote business with beneficial outcomes for society, the environment and human wellbeing (Son et al., 2016; Nikolaidis et al., 2017).

3. NBS for sustainable cities

The value of nature and its benefits to society are increasingly recognized by civic authorities and local citizens. Evidence is provided by the burgeoning number of local, national, and international policy initiatives for the sustainable use of natural capital within urban areas (Daily et al., 2000; Guerry et al., 2015). This is reflected in the numerous bottom-up initiatives, particularly community efforts, adopting NBS to bring nature back into urban areas (EC, 2015). Accordingly, both research and civic communities are focusing on 'people and nature' and generating knowledge for co-designing NBS (Frantzeskaki et al., 2017).

NBS are now in the mainstream and delivered at different scales in all shapes and sizes, supplying various ESS. City trees, for example, take up substantial amounts of carbon dioxide and provide cooler air temperatures, thereby ameliorating the urban heat island effect (Mariani et al., 2016; Ragettli et al., 2017; Willis and Petrokofsky, 2017) and improving the living conditions of vulnerable populations, in particular. The canopy cover and biomass of city trees improve air quality and the urban climate and offer a wide range of recreational and nature experiences for young and old alike, as well as provide habitat for many species of flora and fauna, including rare and endangered species (Naumann et al., 2014; Giannico et al., 2016). Furthermore, NBS like roof gardens, green school grounds and large urban parks can generate economic values due to the cooling energy they save, which would otherwise have to be technically produced (Naumann et al., 2011).

Sustainable water infrastructure planning using an NBS approach can also produce co-benefits that deal simultaneously with storm water flooding and water scarcity due to extensive periods of drought. The good practice examples that follow, one in Europe (The Netherlands) and the other well beyond its borders in Asia (Guangdong Province, China), showcase the potential of NBS emphasizing their multiple co-benefits for sustainable urban development. Certain DPSIR components have been identified for the two case studies presented. For this purpose, we have linked up the DPSIR framework to both examples by including the components (in parentheses) identified: (1) In Nijmegen, The Netherlands, the government-designed program 'Room for the River' was established to address flood protection. NBS were implemented to prevent floods (*pressure*) by lowering the high level of water (*impact*) and offer spatial quality to the area, reconnecting people and rivers (*state*). The project involved two main measures – relocation of the dike inland, and digging an ancillary channel in the floodplain – to allow the creation of a new island. Both NBS actions provided more space for the river and nature. Co-benefits of the program include enhanced risk management (*response*), and opportunities for recreation and nature through the development of an urban river park. Seventeen partners from provinces, municipalities, water boards and the Ministry of Infrastructure and the Environment took part in the project (see: https://www.ruimtevoorderivier.nl/room-for-the-waal); and (2) The city of Shenzhen, in Guangdong Province, China, is faced with heavy downpours (*impact*) during the monsoon season and water scarcity in periods of drought (*pressure*). To brace this dual challenge, the local government adopted NBS for the construction of the Guangming New District. Shenzhen has a sports center equipped with a green roof, raingardens, and permeable pavement which absorbs over 60% of rainfall each year (*state*). In 2011, the district was acknowledged as China's first low-impact development model for having employed NBS in its storm water management plan (*response*) (ICLEI, 2017). The city's municipal government prompted public participation to allocate responsibilities covering maintenance, sanitation, security, commercial operations, etc., to various departments and governmental levels (Wang and Li, 2016).

Knowledge gained through experiences with implementing successful projects where NBS have been introduced is instrumental for effectively employing NBS in urban planning (Kabisch et al., 2016). In their work focusing on NBS for climate change mitigation and

adaptation in urban areas, Kabisch et al. (2016) highlight the importance of exploiting the know-how of policy makers and advisors, citizens, researchers and urban planners concerning NBS in cities and consolidating it. The authors believe, however, that such experience-driven know-how can be obtained and applied when new stakeholders engage with those networks which created or acquired the experiences. Engaging those communities by introducing the promises of the NBS concept can be extremely relevant for the rapid uptake and integration into existing knowledge and for stirring engagement with multiple knowledge-holders.

4. Concluding remarks

Our era, the Anthropocene (Monastersky, 2015), is marked by challenged urban ecosystems that urgently require enhancing their sustainability through the implementation of NBS at a greater speed and larger scale. Although the ongoing EC projects (Table S1) are still insufficient to provide a wide and robust evidence-base, NBS offer tremendous potential for improving the quality of life of urban residents and finding cost-effective solutions to challenges, such as air pollution or flooding. We are called to develop urban planning approaches and measures that allow individuals to seize the innumerable benefits and services that nature provides (e.g., water, food, recreational opportunities) as well as to protect the environment from unsustainable exploitation (IUCN, 2018). From this viewpoint, NBS have evolved and are being confirmed as the way forward by the EC and its Framework Program, H2020.

The reference framework presented in this article adopts an interdisciplinary approach and demonstrates how NBS can effectively function as downstream responses to meet sustainability goals in urban areas and city-regions. The strength of the framework lies in its standardized DPSIR structure (commonly understood by urban planners not only across Europe) and applicative potential, as it allows to disentangle the complex factors and mechanisms underlying the process of sustainable urbanization and to consolidate the close “cause-effect relationship” between ESS and NBS. In other words, the framework functions as a streamlined support tool for city managers and policy and decision makers that breaks down complex concepts through a direct application of NBS for co-developing sustainable cities facing the pressures of urbanization. Furthermore, through its interactive process, or loop system, this cascading framework efficiently serves the purpose of illustrating (*i*) how NBS work well within ecological processes and human–environment interactions, and (*ii*) that NBS are to be considered as the proven response to today's urgent climate change issues at both the local and regional scale. It is hoped that this article will pioneer others in settling the issue for NBS as the undisputable answer to challenged urban areas and societies globally. We would like to conclude by quoting FAO's message delivered during the 2018 World Forum on Urban Forests: “Forests and green spaces can help create more resilient and sustainable cities, and address the challenges of an increasing urban population”; […] “more sustainable models of urban growth are urgently needed” (http://www.fao.org/news/story/en/item/1171796/icode/).

Acknowledgements

This work was carried out under the European Commission's Horizon 2020 research project “productive Green Infrastructure for post-industrial urban regeneration (proGIreg)” (Project ID No.: 776528) and partially supported by the Hui OiChow Trust Fund – General Award, The University of Hong Kong.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.envres.2018.12.063.

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